CONTRACT RESEARCH DIVISION
NATIONAL RESEARCH CORPORATION
A SUBSIDIARY OF NORTON COMPANY
70 Memorial Drive / Cambridge, Massachusetts / 02142

N 65-84631

April 9, 1965

Office of Advanced Research and Technology
Headquarters
National Aeronautics and Space Administration
Washington, D. C. 20546

Attention: Code RRM

Reference: Third Quarterly Progress Report
NASw-962 - NRC Project #86-1-0609

Gentlemen:

This letter report briefly describes the work performed on Contract Number NASw-962, entitled "Study of the Mechanism of Atmospheric Interaction with the Fatigue of Metals" during the period 1 January 1965 to 31 March 1965.

1. Progress on Phase I

During the period under review, approximately 50 fatigue tests at four stress amplitudes in the range 8,000 to 14,000 psi were completed for H14-1100 aluminum in the pressure range 0.6-4.0 x 10^{-7} torr (mean pressure level 2 x 10^{-7} torr). The fatigue tests were run at constant cyclic rates of 25 and 50 cps. During the course of each test, measurements of crack formation and growth rate were obtained; for selected tests, measurements of the bending moment response were taken to examine the effect of repeated loading on the yield stress.

Taking the yield stress of H14-1100 aluminum as about 17,000 psi, the vacuum fatigue tests were run at fixed strain amplitudes in the range 0.001 to 0.002. Within this range, the fatigue lives varied from approximately 4 x 10^6 ($\sim$8400 psi) to 0.1 x 10^6 cycles ($\sim$ 13,500 psi).

Several interesting results were observed in comparison to fatigue data taken at equivalent stress-strain levels in unit atmosphere (7.60 x 10^2 torr). The general results are shown in Figure 1 which compare the total fatigue life N_T of H14-1100 aluminum in atmosphere and at average 2×10^{-7} torr. It is evident that the vacuum environment substantially increased the fatigue resistance by a factor of 2 to 5. It is noteworthy that the effect of varying the cyclic test rate at 2×10^{-7} torr produced a negligible change in fatigue behavior. A similar response was noticed in the tests at unit atmosphere.

In the course of the vacuum fatigue tests, the cyclic life to produce an initial crack N_I (taken as 1% extension across the specimen gauge section) was measured and compared with atmospheric data. These results are shown in Figure 2. At high stress levels corresponding to rapid fatigue, specimens tested in vacuum showed extensive crack formation well before equivalent tests in atmosphere. At low stress levels, crack initiation was somewhat retarded in the vacuum environment. The overall result, however, was that the fatigue life to initiate a dominant crack was somewhat insensitive to the pressure level at the surface.

In contrast to the results for N_I, the comparative data for N_P, the number of fatigue cycles to propagate the crack completely through the specimen, shown in Figure 3, reveal the major effect of vacuum environment on fatigue behavior. The propagation life expressed as $N_P = N_T - N_I$ was increased by factors varying from 5 to 11 over equivalent atmospheric tests. Changes in the cyclic test frequency at 2×10^{-7} torr pressure did not reflect in the fatigue behavior.

Figure 4 summarizes the results obtained at atmosphere and the 2×10^{-7} torr level showing the effect of fatigue stress on the cyclic life ratios of N_T and N_P. The effect of vacuum environment was found to increase with the lower stresses. These results are consistent with generally accepted fatigue mechanisms which predict a greater fatigue sensitivity to surface conditions at low stress levels.

Additional tests are now in progress at a mean pressure level of 1×10^{-5} torr. Preliminary results show that in this pressure range, variations in the cyclic test frequency do substantially effect the fatigue behavior. It is estimated that tests at the 10^{-5} scale will be completed by April 15, 1965. A final series of tests at 10^{-3} torr will then be conducted to complete Phase I of the program.

2. Phase II

In Phase II of the program, a fatigue device is under design for incorporation in the Extreme High Vacuum (XHV) apparatus developed at NRC. After numerous modifications, a design has now been approved which will permit simultaneous testing of up to eight specimens at room temperature. Detailed engineering and design considerations are now being carried out for an integral liquid nitrogen cooled heat shield, electrical feed-through connections, bellows assemblies for pressure equilization and support flanges for the device.

The electromagnetic vibrator to drive the specimens has been obtained and preliminary qualification tests of frequency response and amplitude control have been conducted. It is anticipated that the final unit design will be completed May 15, 1965 and construction started then. It is intended to conduct qualification tests of the test components including the electronic feed back amplitude control circuit prior to termination of the current program.

Very truly yours,

NATIONAL RESEARCH CORPORATION

M. J. Hordon

Monroe J. Hordon
Program Director

MJH/abb

Approved by: Norman Beecher
Norman Beecher
Assistant Director of Research

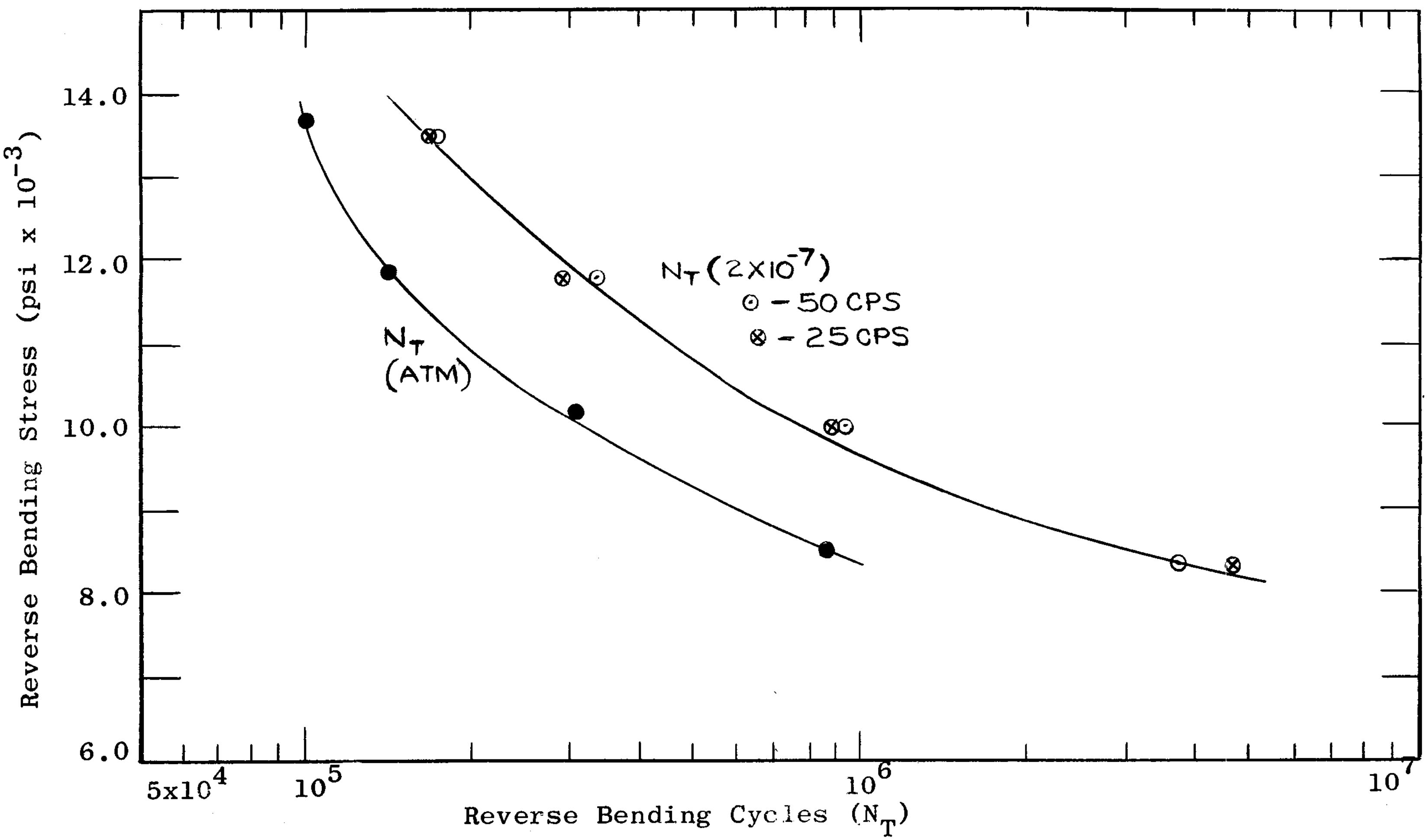

FIGURE 1

VARIATION OF STRESS-CYCLIC LIFE PLOT
FOR H14-1100 Al WITH PRESSURE LEVEL

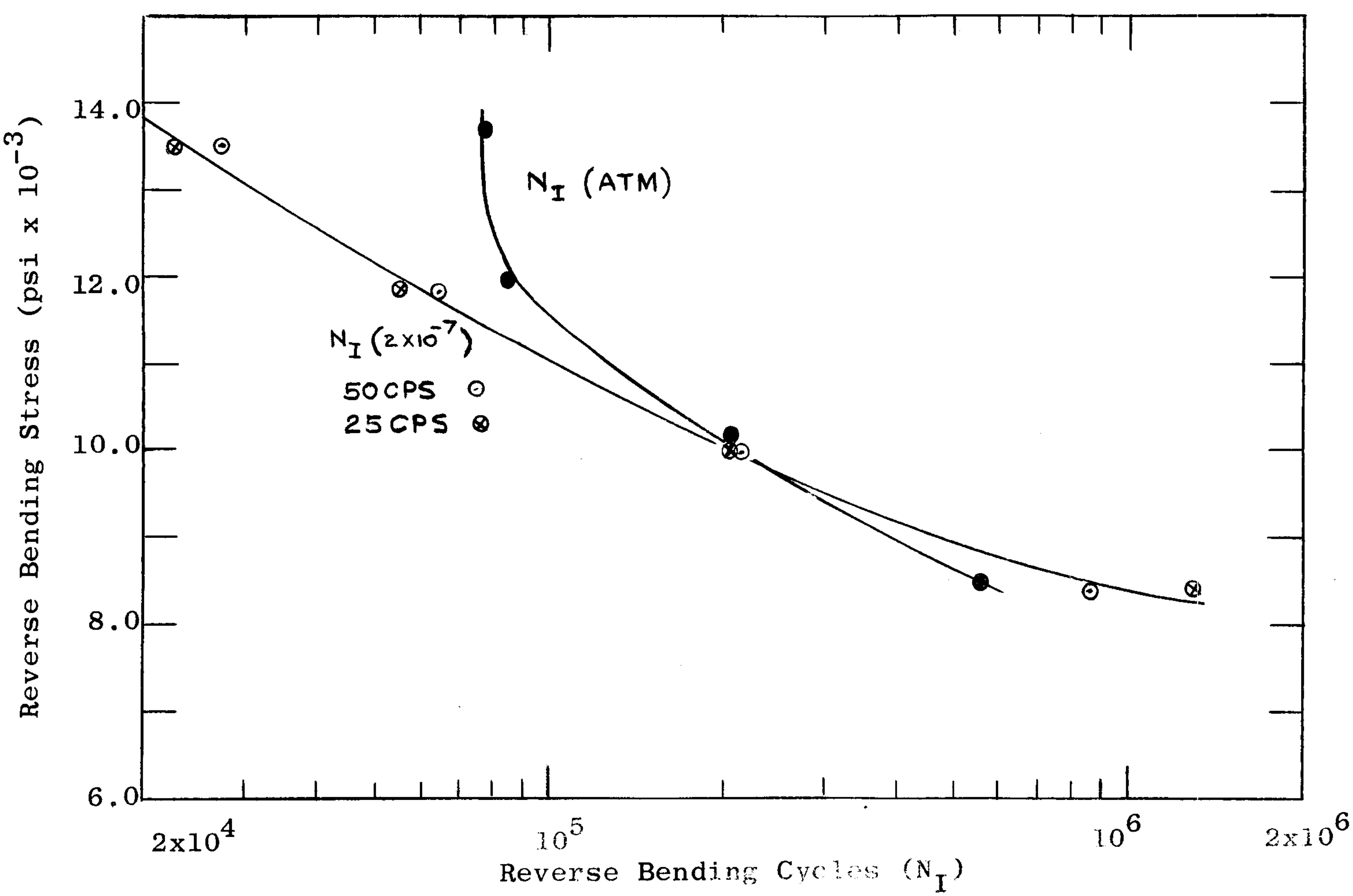

FIGURE 2

VARIATION OF STRESS VS CYCLIC LIFE TO INITIATE CRACK FOR H14-1100 Al WITH PRESSURE LEVEL

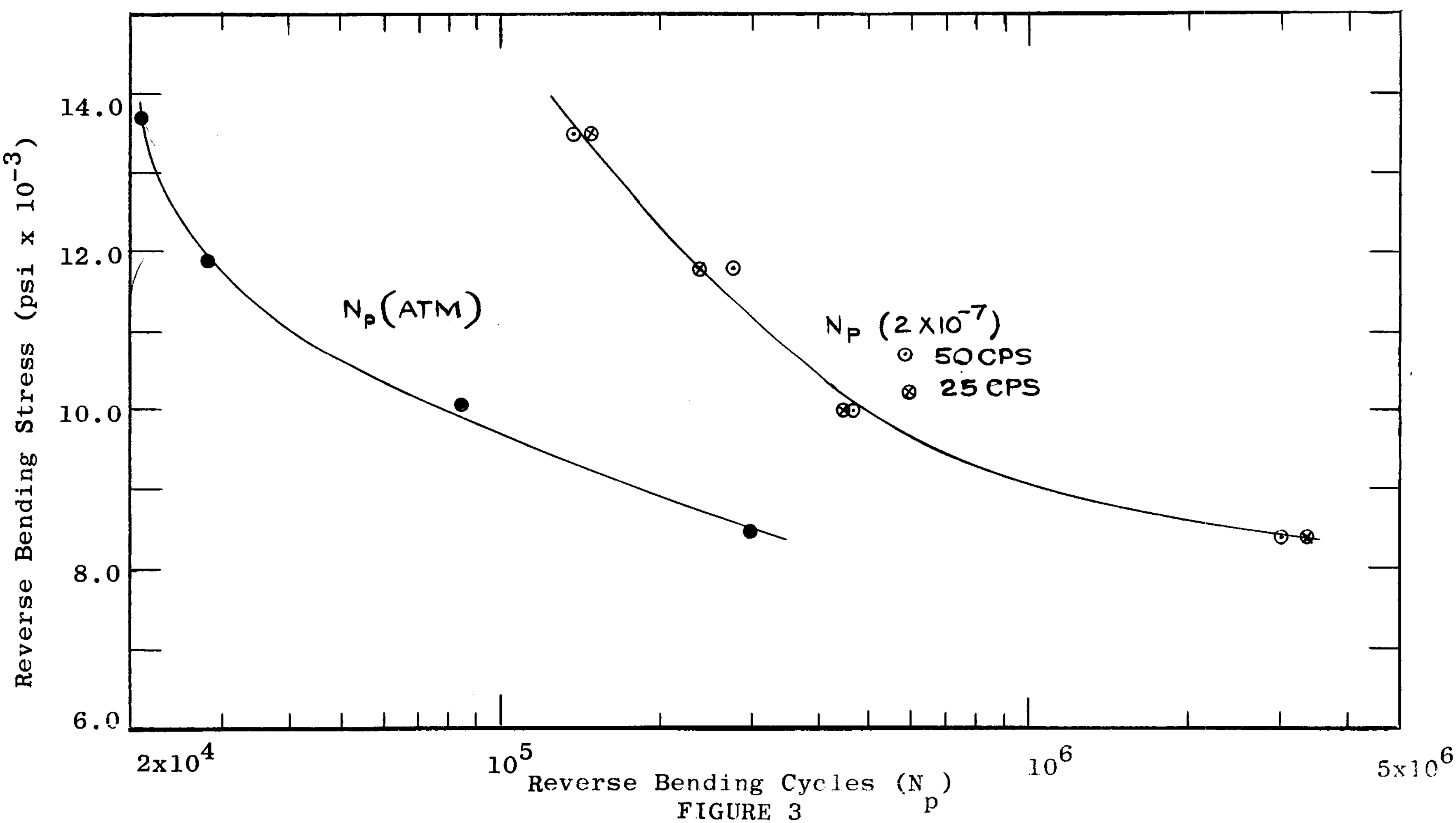

FIGURE 3

VARIATION OF STRESS VS CYCLIC LIFE TO PROPAGATE A CRACK TO FAILURE FOR H14-1100 Al WITH PRESSURE LEVEL

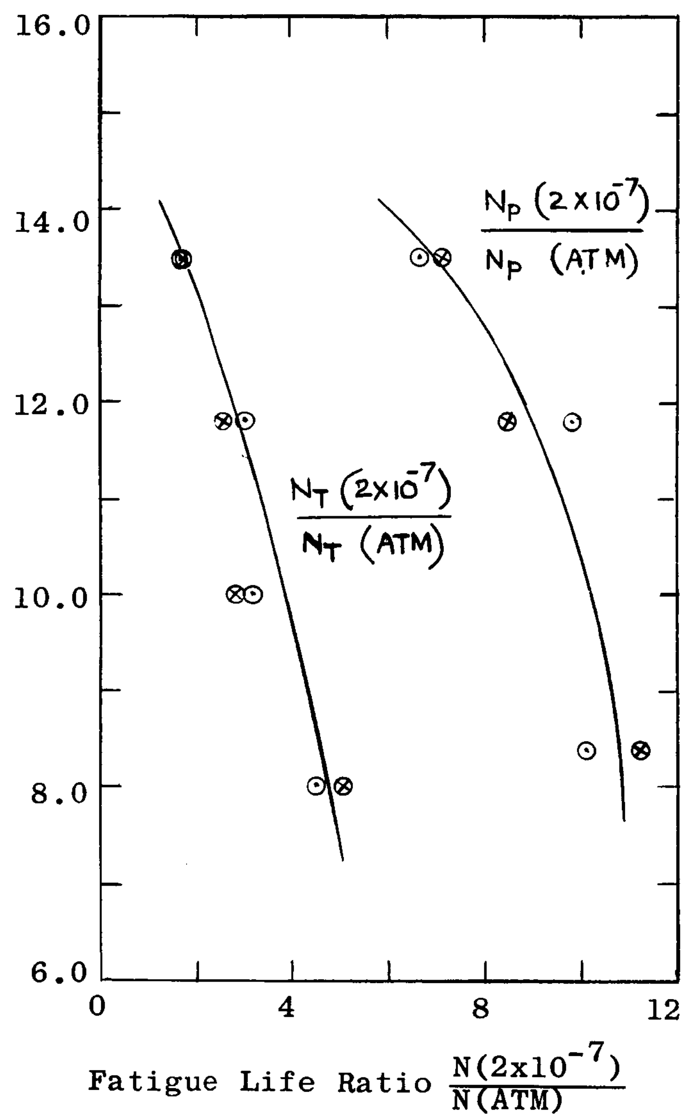

FIGURE 4

VARIATION OF THE IMPROVEMENT RATIO FOR TOTAL FATIGUE LIFE AND PROPAGATION LIFE WITH APPLIED STRESS